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(12) UK Patent Application (19) GB (11) 2 241 287 (13) A

(43) Date of A publication 28.08.1991

(21) Application No 9101798.8

(22) Date of filing 28.01.1991

(30) Priority data
(31) 02012345 (32) 09.02.1990 (33) JP

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(51) INT CL[5]
F04B 17/04

(52) UK CL (Edition K)
F1W WCK W100 W104 W202

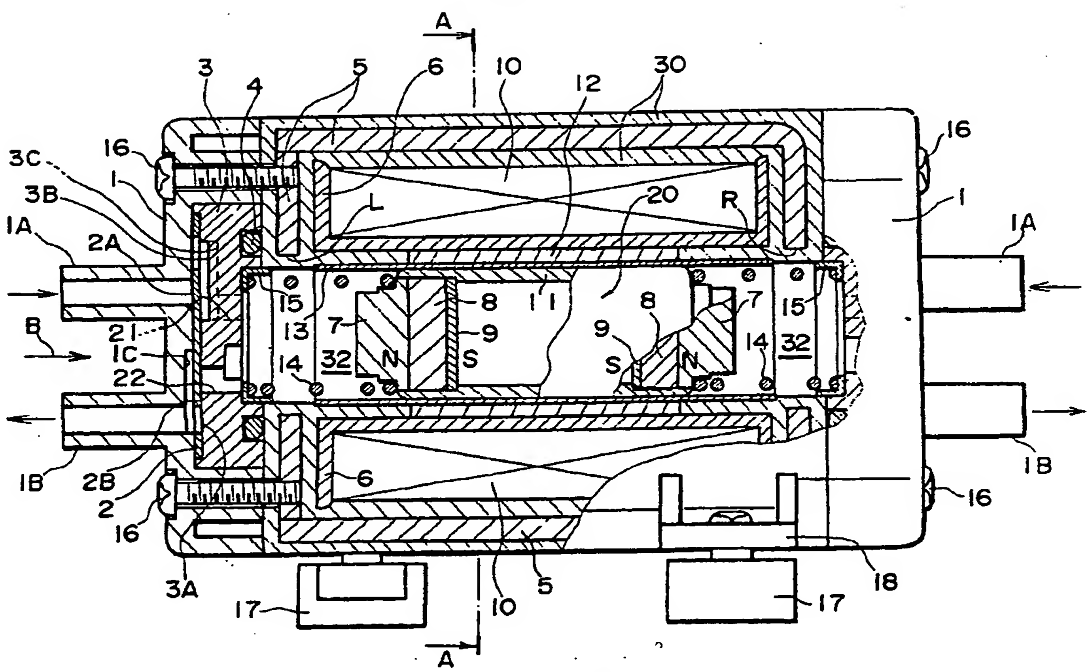
(56) Documents cited
GB 0982261 A US 4749343 A US 4306843 A

(58) Field of search
UK CL (Edition K) F1W WCK
INT CL[5] F04B 17/04 35/04
Online databases: W.P.I.

(54) Electromagnetically driven pump

(57) An electromagnetically driven pump comprises a hollow cylindrical coil (10), a thin-walled bearing (13) of a low permeability material disposed inside the coil (10) and a piston (20) slidable in the bearing, the piston being provided with a piston head (7) and a permanent magnet (8) in at least either the left or right end of the piston main body (11). A spring (14) is provided within the or each working chamber (32) defined by the piston end or ends for restoring the piston to a neutral position, and a stator core (12) is disposed between the central portion of the inner periphery of the coil and the bearing (13). The piston may be a hollow cylindrical assembly. A suction valve (2A) and a discharge valve (2B) are provided for controlling flow to and from the or each chamber (32).

FIG. 1



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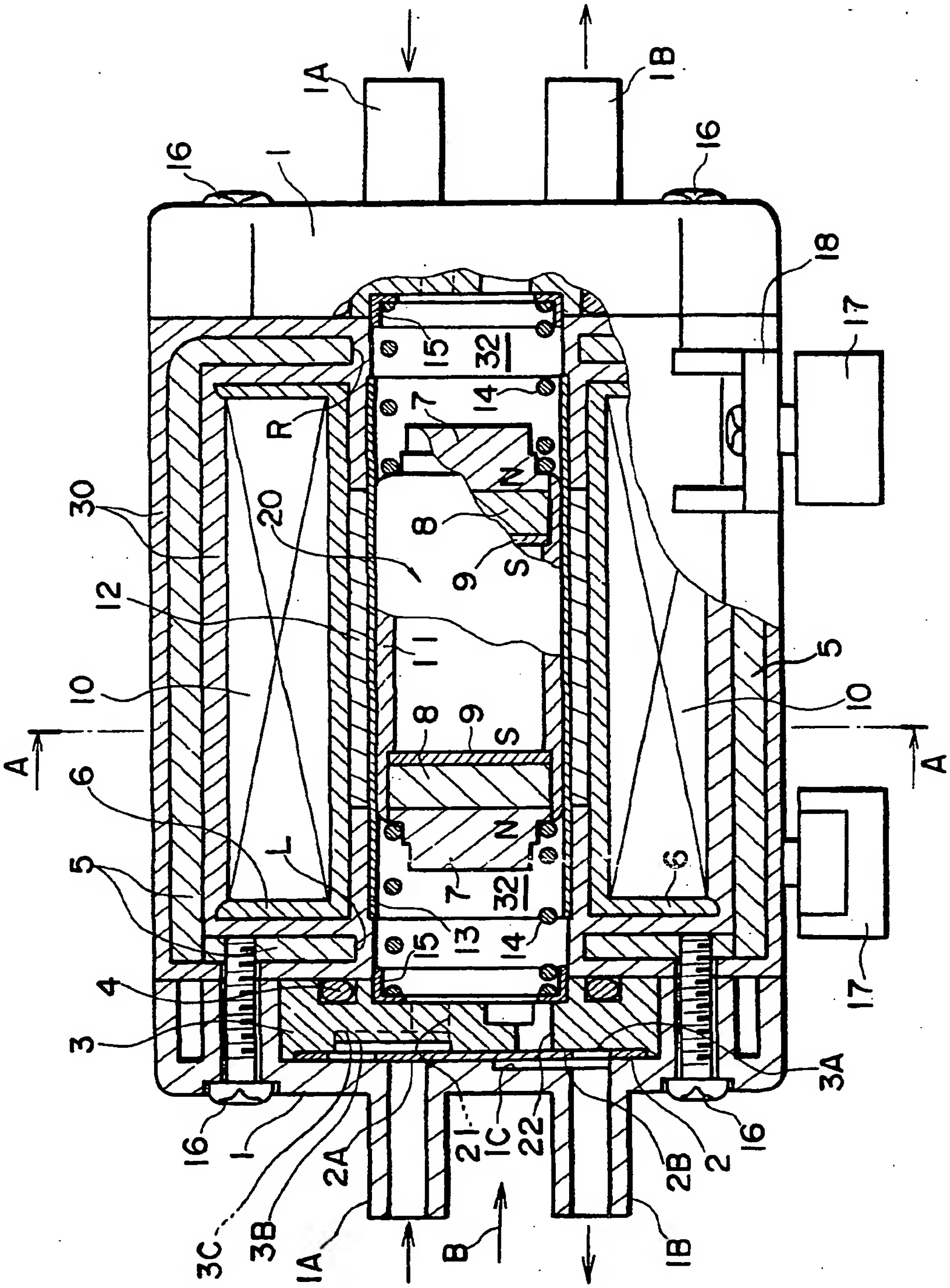
1A
1B
1
16
18
17
15
32
14
7
R
N
30
20
8
9
S
12
11
10
5
A
6
L
13
4
3
3A
3B
3C
2
2A
2B
21
22
1C
B

FIG. 1

FIG. 2

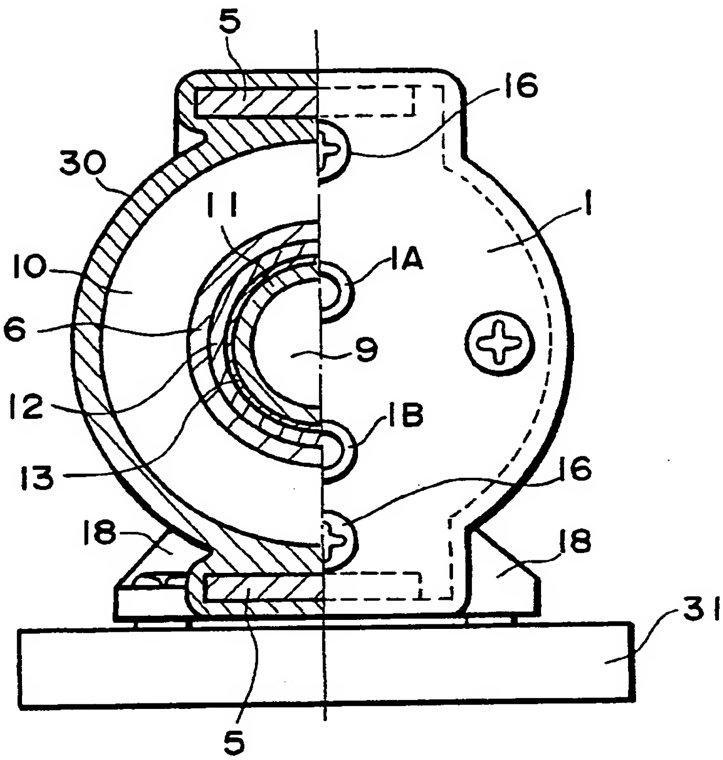

FIG. 3

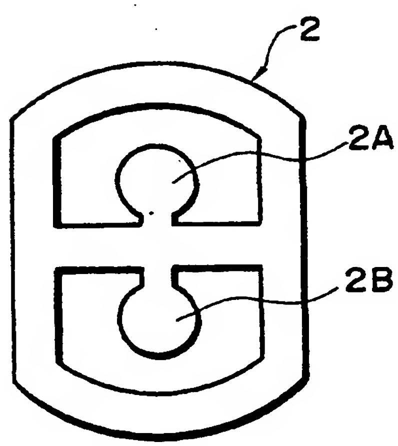

FIG. 4

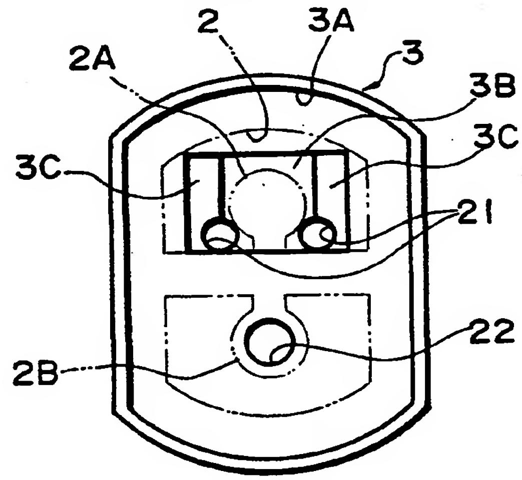

FIG. 5

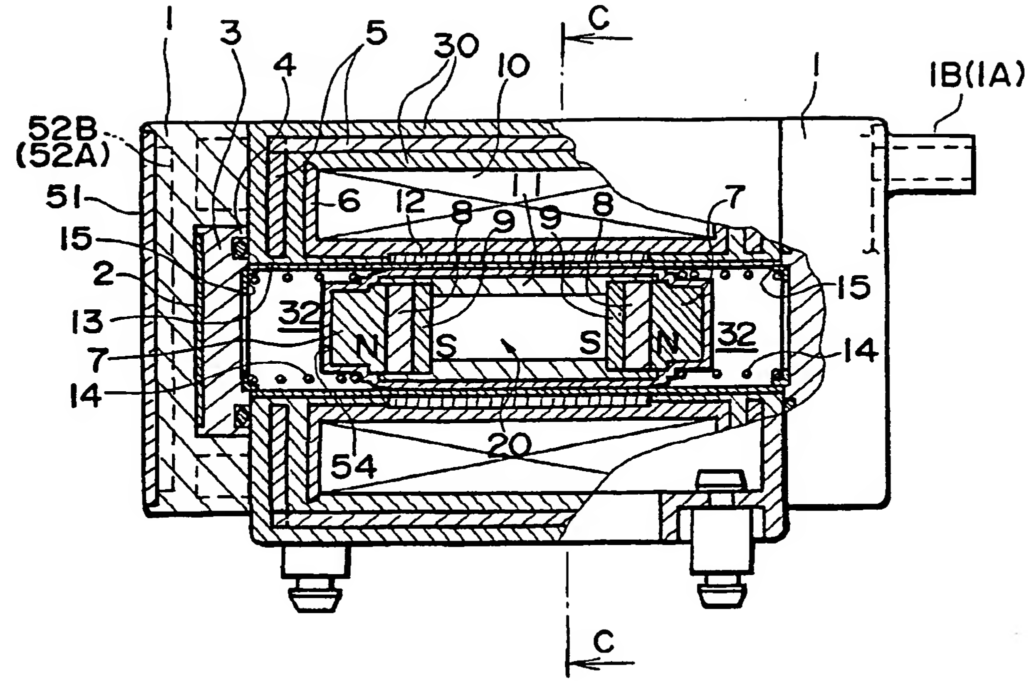

FIG. 6

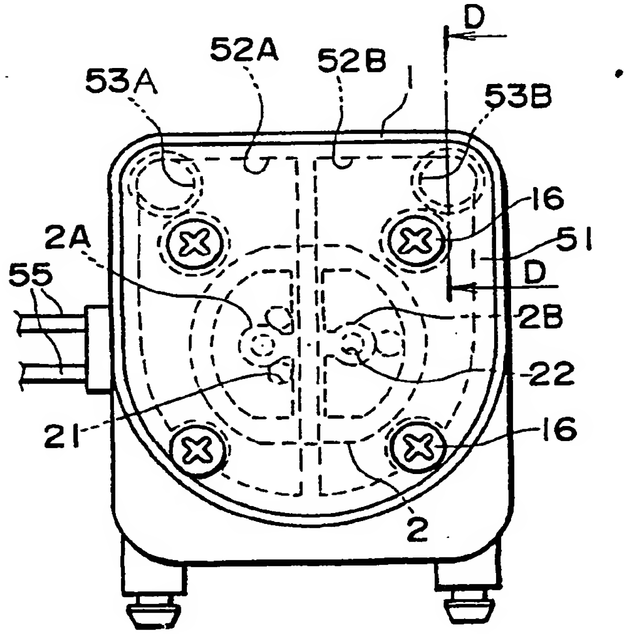

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FIG. 7

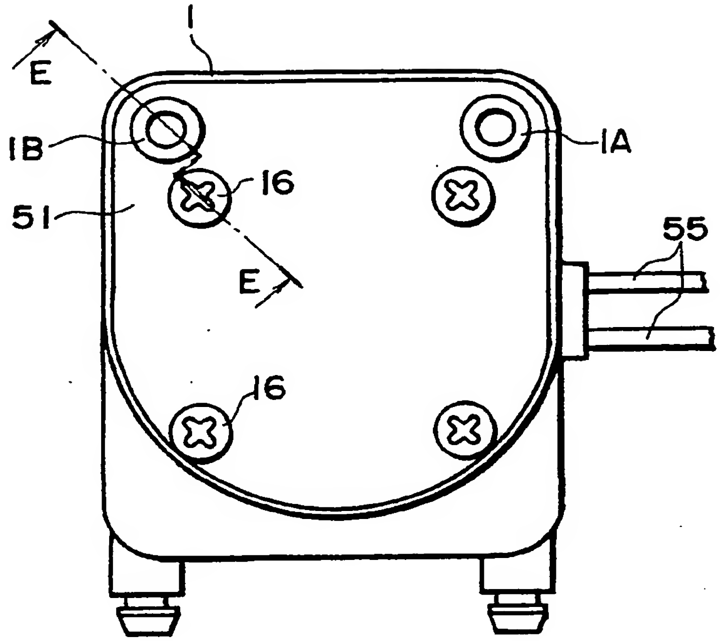


FIG. 8

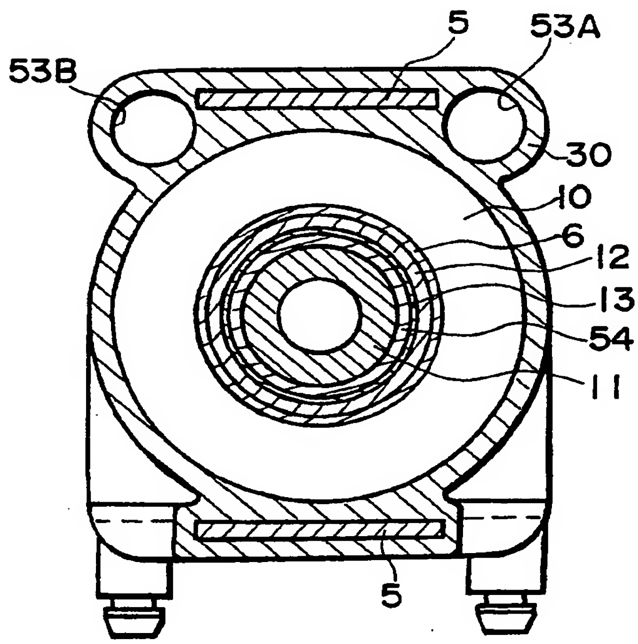


FIG. 9

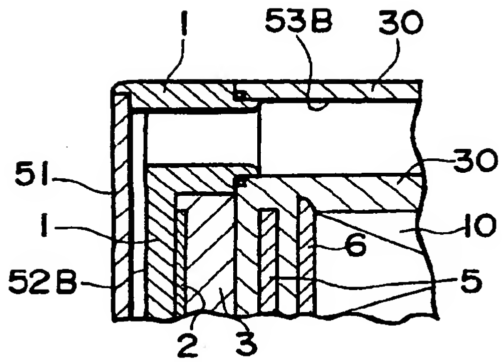
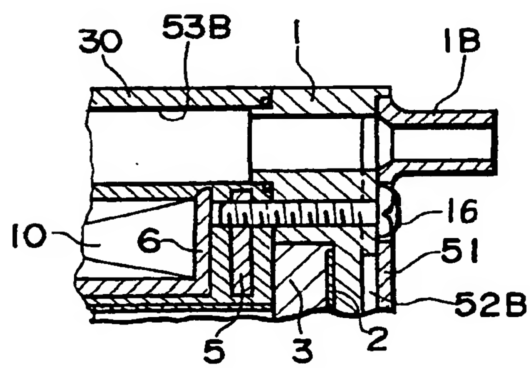


FIG. 10



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ELECTROMAGNETICALLY DRIVEN PUMP

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an electromagnetically driven pump, and particularly to an electromagnetically driven pump or a free piston pump of the type in which a slidably constructed piston (free piston) is reciprocated by an electromagnet and a spring, and the volume of a pressure chamber is changed by the reciprocating motion, thereby to performing the suction and discharge of a fluid.

Description of the Prior Art

As a relatively small-sized compression pump, there has so far been the one in which a diaphragm is coupled with a moving body having a permanent magnet or magnetic member, and the volume of the pressure chamber having the diaphram as one wall surface thereof is changed by operating the moving body using an electromagnetic circuit, thereby performing the discharge and suction of a fluid such as air.

The pump of such type (hereinafter referred to as diaphragm pump) is described in the official gazettes of Patent Application Laid-open Nos. 63-65182, 63-176680, 63-227978 and the like.

The diaphragm pump had the following problems.

(1) Since the diaphragm, which bends each time the moving body reciprocates, is formed of a material such as synthetic rubber which has flexibility, it may be easily damaged. Consequently, its maintenance is cumbersome and expensive.

If the diaphragm is made highly durable to prevent breakage, desired pressure and flow rate cannot be expected and, in addition, it becomes expensive.

Further, the structure of the support for the diaphragm becomes complex and the construction of the diaphram becomes complicated, and the productivity consequently decreases.

(2) Since the moving body is supported by the diaphragm itself, the alignment of axes of the moving body and a core disposed near the moving body can be disturbed, and the moving body can be brought in contact with the core or the like by the flexure of the diaphragm during the operation, and in this case, a noise is made and finally the diaphragm pump may be broken.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a highly durable pump unit which can easily be maintained, simply constructed, and manufactured at a low cost.

The present invention is characterized in that, in order to solve the above problems, a coil is shaped in a hollow cylinder having such an axial length that at least one closed pressure chamber is formed between both ends of the coil, a thin-walled bearing comprised of a low permeability material is disposed on the inner periphery of the coil at least in the extent of the stroke of a piston, the piston is provided with a piston head and a permanent magnet in at least either the left or right end of the piston main body, a spring is provided on the inner periphery of the coil for restoring the piston to a neutral position, and a stator core is disposed between the central portion of the inner periphery of the coil and the bearing. In addition, the present invention is characterized in that the piston is a hollow cylindrical assembly.

When the coil is energized with an alternating

current, the magnet is attracted and repulsed by a flux from the coil, so that the piston always reciprocates in a centrally aligned state maintained by the cylindrical bearing of a thin-walled material, and the volume of the pressure chamber varies, whereby a fluid is sucked into and discharged from the pressure chamber.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a longitudinal sectional view showing an embodiment of the present invention;

Fig. 2 is a cross-sectional view along A - A of Fig. 1 and a side view of the same;

Fig. 3 is a plan view of a flat valve;

Fig. 4 is a representation of the valve seat as seen from the direction of an arrow B in Fig. 1;

Fig. 5 is a longitudinal sectional view of a further embodiment of the present invention showing the main portions thereof;

Fig. 6 is a left side view of Fig. 5;

Fig. 7 is a right side view of Fig. 5;

Fig. 8 is a cross-sectional view of Fig. 5 taken along the C - C line;

Fig. 9 is a cross-sectional view of Fig. 6 taken along the D - D lines; and

Fig. 10 is a cross-sectional view of Fig. 7 taken along the E - E line.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Now, an embodiment of the present invention is described in detail with reference to Figs. 1-4. In Fig. 4, flat valve 2 is shown by imaginary lines. Base 31 shown in Fig. 2 is to receive rubber vibration insulators 17 of Fig. 1, in which the base 31 is omitted for simplefication. In Figs. 1 and 2, cylindrical coil 10 is wound around bobbin 6 molded of a resin.

Cylindrical stator core 12 formed of a magnetic

substance such as low-carbon steel is placed in the center inside bobbin 6. Also, inside the stator core 12, bearing 13 formed of hard glass, stainless steel, brass or the like is disposed the thickness of which is made as thin as possible. Although the sectional shape of the bearing is made cylindrical in conformity with the sectional shape of a piston which is described later in more detail, it may not be cylindrical but in any other surface if it is a surface suitable for fluid-tightly and slidably supporting the outer peripheral surface of the piston.

Outside the cylindrical coil 10, york core 5 is arranged which is formed of a magnetic substance of low-carbon steel or the like. The bobbin 6 and stator core 12 are molded 30 by a resin so that their relative positional relationship is fixed. The molding 30 is performed so as to expose the inner wall surface of the bearing 13.

The piston 20 is fluid-tightly and slidably disposed within the bearing 13. The piston 20 has a cylindrical main body 11 formed of a non-magnetic material such as a resin, carbon and aluminium in the central portion thereof, and it comprises pairs of front magnet yorks 7, permanent magnets 8 and rear magnet yorks 9 which are fixed to both ends of the piston main body 11, and a pair of front magnet yorks 7 constitute two, piston heads.

It is preferred that the front and rear magnet yorks 7 and 9 are formed of a magnetic substance such as low-carbon steel and the magnets 8 are formed of a rate earth material. The rear magnet yorks 9 are in the shape of a sheet and are disposed at both ends of the piston main body 11 with a required spacing therebetween. The permanent magnets 8 are disposed on both outsides of

th m and front magnet yorks 7 are further disposed on both outsides of them in this order, and they are fixed to both ends of the piston main body 11 so that they are closely contacted with each other. The pair of permanent magnets 8 are disposed so that the sides opposed to each other have the same polarity. In the example shown in Fig. 1, each permanent magnet 8 is placed so that the rear magnet york side is the south pole.

When the cylindrical coil 10 is not energized, piston 20 is supported by a pair of springs 14 in a balanced state so that it is positioned in the central portion of the cylindrical coil 10 (neutral position) or in the central portion of the stator core 12.

To both ends of the cylindrical coil 10, head covers 1 formed of a resin or the like are attached via O-rings 4, valve seats 3 and flat valves 2. The attaching is performed by screwing bolts 16 into york core 5.

The flat valves 2 are sheet-like valves which are formed of flexible material such as synthetic rubber, and are provided with a pair of valve bodies (suction valve 2A and discharge valve 2B) as shown in Fig. 3. The valve seat 3 is molded of a resin or the like, and as shown in Figs. 1 and 4, it has a first recess 3A which is dug in the outside surface thereof with a depth substantially same as the thickness of the flat valve 2 and with the same outline as that of the flat valve 2 (in this case, eliptical) for receiving the flat valve 2, a second recess 3B which is dug in the first recess 3A more deeply than the first recess 3A in a position opposed to the suction valve 2A, and third recess 3C formed still more deeply than the second recess 3B so as to be fluidly connected to the second recess 3B.

In the portion of the valve seat 3 where the third

recess 3C is formed, fluid passages 21 are formed so as not to be opposed to suction valve 2A. In the portion of the valve seat 3 which has the first recess 3A formed therein and is opposed to discharge valve 2B, fluid passage 22 is formed. The fluid passage 21 and 22 pass through the valve seat 3.

The head cover 1 has a suction inlet 1A formed in a position opposed to the suction valve 2A of the flat valve 2, and has a recess IC formed in a position opposed to discharge valve 2B on the inside surface thereof, which recess 1C is larger than the outline of the discharge valve 2B and communicating with discharge outlet 1B.

As shown in Fig. 1, the flat valve 2 is mounted between the valve seat 3 and the head cover 1 so as to be pressed by them. Normally, suction valve 2A is fluid-tightly contacted with the perimeter of suction inlet 1A, and discharge valve 2B is fluid-tightly contacted with the perimeter of fluid passage 22 formed in valve seat 3.

The pair of springs 14 are disposed between the pair of valve seats 3 and both ends of piston 20, and formed of a stainless steel wire or the like. A pair of spring seat 15 formed of stainless steel plate or the like receive the ends of springs 14, respectively.

Leg portions 16 are formed in and integrally with the lower part of the molding portion 30, and rubber vibration insulators 17 are attached to the bottoms of them. The rubber vibration insulators 17 are received in base 31 (Fig. 2).

As seen from Fig. 1, by airtightly attaching the valve seats 3 to the molding portion 30 via O-rings 4, a pair of sealed pressure chambers 32 are formed between the respective valve seats 3 and both ends of piston 20.

In operation of the present embodiment, an alternating current such as a commercial alternating current flows in cylindrical coil 10, a magnetic flux passes through the magnetic circuit formed between the york core 5 and the stator core 12. Since no magnetic material is disposed between the end portions of york core 5 at both sides of cylindrical coil 10 (the portions designated by symbols L and R) and both ends of stator core 12 (that is, a non-magnetic region lies between them) and a leakage flux occurs, south and north magnetic poles alternately occur in both inner end portions L and R of the york core 5 and both ends of stator core 12.

For instance, in one half wave of the alternating current, if the south pole appears in portion L and the north pole appears in the left end of stator core 12, and the south pole in the right end of the stator core 12 and the north pole in portion R then piston 20 slides to the left side of Fig. 1 by the magnetic attraction between the magnetic poles and magnets 8. Then, in the other half wave, the respective magnetic poles of the respective portions are reversed, the piston 20 slides to the right side of the same figure.

Accordingly, if the natural frequency of the piston 20 system of the pump is previously made to substantially match the frequency of the power supply applied to cylindrical coil 10, piston 20 is put in a resonance state and reciprocates. By the reciprocating motion of the piston 20, a fluid such as air is introduced from suction inlet 1A through suction valve 2A, third recess 3C and fluid passages 21 into the pressure chamber 32, and discharged from discharge outlet 1B through fluid passage 22, discharge valve 2B and recess 1C.

Although, in the pump shown in Fig. 1, a pair of

pressure chambers 32 are formed at both sides of piston 20 and two pairs of suction inlets 1A and discharge outlets 1B are provided so as to communicate with the respective pressure chambers 32, and the two pairs of suction inlets 1A and discharge outlets 1B are separate, the two suction inlets 1A and the two discharge outlets 1B may be commonly connected each other in parallel, respectively. By this connection, the pairs of the discharge outlets and suction inlets of the pump are collected into one, respectively. Also, one discharge outlet 1B may be connected to the other suction inlet 1A to make a series connection of the two pressure chambers. The fluid passages for these parallel or series connection may be formed within the mold portion 30.

The second embodiment of such parallel connection is described below refering to Figs. 5 through 10. In Fig. 7, for clarity, the hidden outlines of flat valve 2, fluid chambers 52A, 52B, fluid passages 53A, 53B, etc. as shown in Fig. 6 are omitted. In Figs. 5 through 10, the same symbols as those in Figs. 1 through 4 represent the same or identical portions, and thus the description thereof is omitted. In the respective figures, symbol 55 represents the lead wires taken out from cylindrical coil 10 of the electromagnetically driven pump.

In the second embodiment, the suction inlets 1A and discharge outlets 1B arranged at both ends of the electromagnetically driven pump shown in Fig. 1 are connected with a pair of fluid chambers 52A and a pair of fluid chambers 52B to be described later, respectively, and the fluid chamber pair 52A and fluid chamber pair 52B are connected to fluid passages 53A and 53B to be described later and connected to common suction inlet

1A and discharg outlet 1B (Figs. 5 and 7), respectively.

In Figs. 5 through 10, the fluid chamber pairs 52A and 52B are the recesses formed in the head covers disposed at both end sides of piston 20, and are blocked by cover 51, respectively. In Fig. 5, the representation of fluid chambers 52A and 52B arranged in the right side of the same figure is omitted.

Pressure chambers 32 disposed at both ends of the piston 20 are connected to the fluid chambers 52A and 52B via suction valve 2A and discharge valve 2B of flat valve 2 in a manner similar to that stated before with reference to Fig. 1. The pair of fluid chambers 52A and the pair of fluid chambers 52B are communicated with each other by fluid passages 53A and 53B, and they are connected to suction inlet 1A and discharge outlet 1B, respectively.

As described above, suction valve 2A and discharge valve 2B respectively disposed at both ends of piston 20 may be communicated with each other by fluid passages 53A and 53B formed in the mold portion 30.

Modification 1: Although, in Fig. 1, a pair of springs 14 for supporting the piston 20 are provided at both ends of the piston 20, the spring 14 may be provided at only one end. In this case, the spring 14 needs to be fixed to the spring seat 15 and the end of piston 20 (in this example, front magnet york 7) so that it does not disengage from them.

Modification 2: Although, in Fig. 1, two magnets 8 are provided at both ends of the piston 20, the magnet 8 may be provided at only one end. In this case, since it is not required that, at the side where the magnet 8 is not provided, a non-magnetic region is provided and a pole is formed, one end of york core 5 (portion L or R) and the end of stator core 12 are connected by a magnetic

material. This can reduce the energy loss due to the leakage flux.

Modification 3: Although the piston 20 shown in Fig. 1 is constructed so that the front magnet yorks 7 placed at both ends thereof are exposed, the whole piston 20 may be molded of a resin or the like as shown by symbol 54 in FIg. 5 so that the magnetic substances, magnets and the like are not exposed. In this case, the front magnet yorks 7 and the like are prevented from rusting and the reciprocation of the piston 20 can always be performed well.

Modification 4: The above described pump can be applied not only as a compression pump but also as a small-sized vacuum pump.

As apparent from the above description, the following effects can be accomplished by embodiments of the present invention.

(1) Since the reciprocation motion of the piston as well as the suction and discharge of a fluid can be performed without using a diaphragm, there is no diaphragm breakage and thus the durability and reliability of the pump increase.

(2) Since the piston is disposed on the inner periphery of the cylindrical coil through a bearing, the piston can always be maintained in a centrally aligned state and slided stably, so that the possibility of fault occurrence of the pump unit is small, and in the manufacturing, the production cost can be reduced because of the simple construction.

(3) If the piston has a structure which is symmetrical with respect to the front and rear thereof, and if a pair of springs are loaded at both front and rear ends of it respectively, the stroke of the piston becomes constant. In addition, the setting of the spring

constant of the springs is easy as compared with the diaphragm pump, an operation which is always stable can be expected.

(4) Since the magnetic flux can effectively be utilized, if the reciprocating motion of the piston is performed by means of the permanent magnets provided at both ends of the piston, the efficiency of the pump unit increases and a contribution can be made to making the pump unit small-sized.

(5) Provision of pressure chambers at both ends of the piston enables the reciprocating motion of the piston to efficiently be transmitted to the operations of sucking and discharging a fluid, and the efficiency of the pump unit consequently increases.

CLAIMS

(1) An electromagnetically driven pump comprising:

a cylindrical coil,

a piston disposed inside the cylindrical coil and being slidable in the central axis direction of the coil and provided with a piston head at at least one end thereof,

at least one permanent magnet attached to the piston,

a closed pressure chamber constructed so that its volume varies in response to the sliding of the piston,

a suction inlet and a discharge outlet connected to the pressure chamber, respectively,

a suction valve and a discharge valve which are respectively disposed between the pressure chamber and the suction inlet and discharge outlet,

a thin-walled bearing made of a low permeability material which is disposed on the inner periphery of the coil at least in the extent of the stroke of the piston,

at least one spring disposed within the coil for holding and restoring of the piston at end to a neutral position,

a york core disposed along the outer periphery of the cylindrical coil, and

a stator core disposed at a portion which is on the inner periphery of the cylindrical coil and is not opposed to the magnet in the central axis direction of the coil.

(2) An electromagnetically driven pump of claim 1 wherein the piston is formed in a hollow closed-end shape.

(3) An electromagnetically driven pump of claim 1 or 2

wherein the closed pressure chamber is formed in the coil at both ends in the central axis direction thereof.

(4) An electromagnetically driven pump of any one of claims 1 to 3 wherein a front york member is fixed to the closed pressure chamber side of the permanent magnet in the central axis direction and a rear york member is fixed to the opposite side thereof.

(5) An electromagnetically driven pump of claim 4 wherein the front york member constitutes a piston head.

(6) An electromagnetically driven pump of claim 5 wherein at least the portion of the front york member which acts as the piston head is covered with a resin or the like.

(7) An electromagnetically driven pump of claim 5 wherein the whole piston is covered with a resin or the like.

(8) An electromagnetically driven pump of claim 1 wherein a pair of piston heads are provided at both endsof the piston, a pair of closed pressure chambers are formed within the coil at both ends in the central axis direction thereof, and the suction inlets and discharge outlets of the respective pressure chambers are commonly communicated with each other in a pump main body and each connected to a common suction inlet and a discharge outlet.

(9) An electromagnetically driven pump of claim 1 wherein a pair of piston heads are provided at both ends of the piston, a pair of closed pressure chambers are

formed within the coil at both ends in the central axis dir ction thereof, and

in the pump main body, the suction inlet connected to one pressure chamber is connected to the discharge outlet connected to the other pressure chamber, and the discharge outlet connected to the one pressure chamber and the suction inlet connected to the other pressure chamber are adapted to be connected to an external devices.

(10) An electromagnetically driven pump substantially as hereinbefore described with reference to and illustrated by any one of the accompanying drawings.

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